Daylighting on the Cutting Edge in Utah

The State of Utah Department of Natural Resources uses daylighting design to save money and set a new standard for energy-efficient office construction.

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The Utah Department of Natural Resources (DNR) recently cast its resource management philosophy in concrete (not to mention steel, glass, landscaping and recycled materials). In May, 1996, the Department completed what may well be the most energy-efficient office building in the state. Its new headquarters in Salt Lake City is designed to cost half as much to light, heat and cool as a typical office building, saving taxpayers about $50,000 per year in energy bills. And at a price tag of almost $10 million, the DNR project cost only about $300,000 more than what a conventional building would have cost. Using simple off-the-shelf technologies and design approaches, the three-story 105,000-square-foot (9755-m^2) facility sets a new standard within the state for office comfort and resource efficiency.

Whole-Building Design

The Utah DNR's new building was born out of a desire to better serve the public and facilitate resource management by bringing the departmental offices together under one roof. In addition, the DNR wanted to achieve state-of-the-art energy efficiency while saving money and creating a comfortable and productive environment for employees and visitors. With these goals in mind, the Department selected a design team of architects, engineers and construction professionals to take on the project.

Lead architect David Brems points to a conceptual shift in building planning as the core innovation behind the design team's success. Instead of seeing the new building as simply a collection of architectural and mechanical features or parts, the design team approached the project as a dynamic whole system of interacting people, spaces, materials and energy. This allowed the designers to achieve multiple and interrelated goals through strategies and technologies that work synergistically with each other.

Lighting Efficiency

In their quest for integrated energy efficiency, the design team began by creating a high aspect ratio (length in proportion to width) and then orienting the building appropriately to the sun. The building is 275 feet (83.8 m) long, from east to west, and 125 feet (38.1 m) wide, from north to south. Almost all of the glazing (window area) is on the long north- and south-facing sides, with 4200 square feet (390 m^2) on the south and 3800 square feet (353 m^2) on the north. This orientation of glazing to the sun's path is the first step in optimal daylighting design, which allows natural light to enter the building without creating unwanted heat gain or glare for occupants near the windows. The potential for heat gain and glare is greatest on the east and west sides, where the sun angles are most direct at sunrise and sunset. Direct sunlight is not a problem on the north side of the building and is easy to control on the south side with shading structures.

To shade south-facing windows from glare and heat gain, and to help bring natural light deeper into the office interior, the architects equipped the building with external and internal light shelves. As sunlight passes through the glazing above the light shelves and is reflected onto the ceiling, it penetrates between two and three times farther into the interior of the office than it otherwise would (see diagram, page 26). Light entering windows below the light shelves provides a welcome daylighting effect without glare or heat gain. The deep penetration of natural light is aided by the open floor plan, in which most private offices are positioned at the core of the building and have clerestory windows that admit "borrowed" light from the open office space around them.

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The design team optimized lighting savings by fully integrating the daylighting effect created by the glazing and light shelves with the electrical lighting system. Efficient T-8 lamps with electronic ballasts are mounted in indirect fixtures that reflect light off the ceiling. As the level of natural light increases in the space, daylight sensors and special dimming ballasts reduce the electrical light output, thus saving energy while keeping the ambient illumination level constant. Because the indirect fixtures hide the lamps from view, occupants don't notice the dimming process. This is important to their continued perception of having enough light. Occupancy sensors in all office spaces also help save electricity by turning lights off and on as people leave and enter.

Photo Unavailable

The result of the combination of daylighting design features and advanced lighting technologies is an office environment that feels good to employees and impresses visitors. "A comment that people often make," says DNR energy engineer Jim Wingerden, "is that the building has a very nice bright airy feel to it." According to Wingerden, this is due not only to the daylighting and indirect lighting combination, but also to the light-colored surfaces and wall-washing lights around the offices at the core of the building.

Cooling and Heating

A second and very important benefit of the building's daylighting design is that it reduces cooling loads. Most of the heating load in a typical office building comes from electric lighting and direct solar gain through east and west glazing and unshaded south-facing windows. The design of the Utah DNR building all but eliminates these sources of heat gain, thus greatly reducing the energy needed for cooling.

The cooling reduction effect of the daylighting design is complemented by appropriate insulation levels in the building envelope itself, which reduces both cooling and heating loads. The walls are insulated with fiberglass batts and external rigid insulation to an approximate R-28. And the ceilings have 3 inches (7.5 cm) of rigid insulation and 2 inches (5 cm) of sprayed-on fireproofing under a metal deck for an R-value of about 25. The glazing is high-performance, low-e glass that transmits a high level of visible light and excludes much of the invisible wavelengths that convert into heat.

Integrated with the variable air volume (VAV) system, which handles ventilation, cooling and heating, a highly efficient four-stage system meets the greatly reduced cooling load. First, an economizer cycle brings in outside air directly if it is cool enough. Second, air is pulled in through a direct evaporative cooler (swamp cooler), which cools the air and adds humidity. If even cooler air is called for, an indirect evaporative cooling tower mounted on the roof kicks in. And finally, if these methods are not enough, air in the building moves through a conventional chiller. Project architect Jim Nielson says he expects the chiller to operate only about ten days out of an average year.

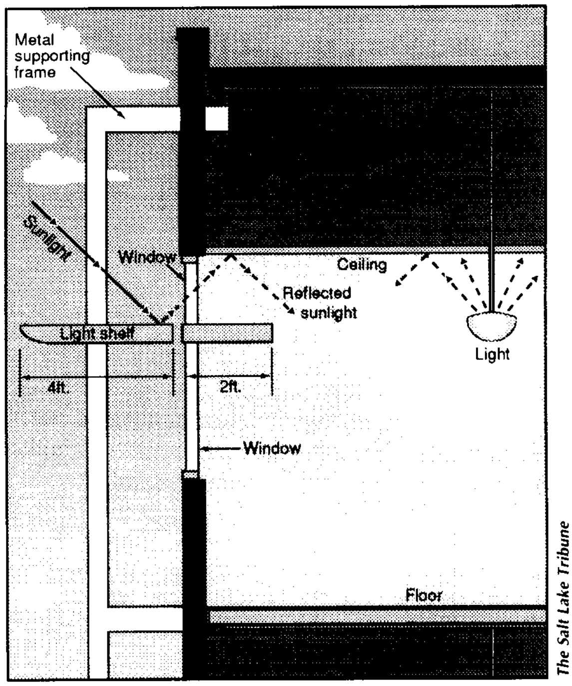
Most of the winter heating load is met by a gas-fired hydronic finned-tube system that heats the space adjacent to the windows. On the very coldest days, heat-exchanging boilers provide warm air to the VAV system. The efficiency of the HVAC system is greatly enhanced by variable speed fan drives and high-efficiency motors.

High Energy Performance

Computer modeling, using the DOE2 software created by the Lawrence Berkeley National Laboratory for the U.S. Department of Energy, provided the design team with energy performance predictions and optimization assistance. Based on the modeling, designers expect the new office building to use about 43 percent of the energy predicted for a reference design that meets current energy codes (see Project Details sidebar).

Lighting use will be cut in half and the cooling load should be almost 90 percent less compared with a conventional building. This dramatic reduction in cooling is a synergistic result of the combination of the daylighting design, envelope treatment and the highly efficient mechanical cooling system. Because daylighting greatly reduces the need for cooling, the building can use more efficient methods most of the time and rarely use the high-energy-consuming chiller.

The heating load is about 10 percent greater in the DNR headquarters than it would be in a typical office. This is due to a combination of reduced heat gain through windows, reduced heat gain from electric lights and increased heat loss through the building envelope, which because of the high aspect ratio has more exterior surface area than most buildings of comparable size.



Light shelves on the Utah Department of Natural Resources building

Saving Tax Dollars

Designers expect the annual dollar savings for the new office building to be even greater, proportionally, than the energy savings. This is because they concentrated on reducing lighting and cooling loads, which require expensive electricity, while doing little to impact the heating load, which is met relatively inexpensively with natural gas. Wingerden calculates that a building designed to the baseline (code) specifications would generate energy bills of about $100,000 annually. He expects the DNR building to require about half of that, which means an annual savings of $50,000.

At a construction cost of about $10 million, the extra cost of this energy-efficient building was only 3 percent of the total, or $300,000. The external and internal light shelves accounted for most of this extra cost. The expense of including most of the other energy-saving features was roughly canceled out by equipment savings related to the energy-efficient design. For example, the chiller is much smaller than that required for a typical office of this size and fewer lamps are needed to meet the reduced lighting requirements.

The DNR plans to recoup the extra initial cost of daylighting and energy efficiency in about six years. Thereafter, the state will be saving $50,000 per year on energy bills alone. But energy is not the only story. As David Brems points out, "people prefer to work in daylit spaces because daylighting provides the best possible light and gives users a connection to the world around them." Although difficult to quantify, this translates to greater productivity. Because personnel costs are by far the largest expenditure associated with the building (accounting for $320 million out of $345 million over a 30-year life cycle), even a small increase in productivity can mean huge savings. With this in mind, the Utah DNR expects to save taxpayers close to $18 million over 30 years on its new building.

Leading the Way

True leadership in government is always a welcome occurrence. The Utah DNR has demonstrated its willingness to be on the cutting edge as it has taken giant steps down the path of the resource efficiency it espouses. Not only has the DNR saved energy and money in its new office, but also landscaped for beauty and low water usage, installed water-conserving fixtures, used recycled wood and purchased outdoor furniture made from recycled plastic and aluminum. While its approach to building has been eminently practical, the DNR has also set an inspiring example for others to follow. ☼

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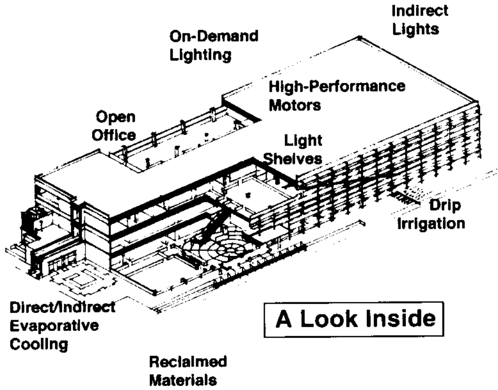
This is one in a series of SOLAR TODAY articles describing successful sustainable energy buildings throughout the U.S. The series is part of the Buildings for a Sustainable America Education Campaign, cosponsored by ASES and the Passive Solar Industries Council. This article was written for the Office of Building Energy Technology, State and Community Programs, U.S. Department of Energy (DOE), through the National Renewable Energy Laboratory (NREL) in Golden, Colorado, and under the guidance of Mary Margaret Jenior (DOE Office of Building Technology, State and Community Programs) and technical oversight of Ron Judkoff, Paul Torcellini and Doug Balcomb (NREL). NREL developed the energy analysis software used in the majority of these case studies. Work currently underway in the DOE Passive Solar Program at the National Renewable Energy Laboratory is providing designers with improved technologies and design tools to use in producing cost-effective, high-performance passive solar designs.



The Buildings for a Sustainable America Education Campaign is sponsored by the American Solar Energy Society, the Passive Solar Industries Council and the U.S. Department of Energy Office of Building Technology, State and Community Programs, through the National Renewable Energy Laboratory.

The BSA campaign is a nationwide effort to make policymakers, building professionals and consumers more aware of the benefits of applying sustainable energy principles to building design and construction. These benefits include increased affordability, more jobs, improved health, reduced energy consumption and less environmental impact.

Here's how the Utah DNR office building stacks up:

Energy
43 percent overall reduction in total energy load, not including office equipment or water heating.

Affordability
The construction cost of $10 million was within the tight budget and only about 3 percent ($300,000) more than a baseline building. The Utah DNR should save about $50,000 per year on energy bills. The simple payback period is about 6 years.

Jobs and Economy
Dollars not spent on energy are spent elsewhere in the state economy, creating more jobs than if the same dollars were spent on conventional energy supply.

Health and Productivity
From the many positive comments, it appears that natural lighting in the office space has a positive physiological and mental impact on the employees and may result in increased productivity.

Environment
The large reduction in electricity consumption reduces the negative impacts of coal-fired power plants in Utah, eliminating an estimated 300 tons of air pollutants each year and reducing land degradation and human health problems associated with coal production and air pollution. Using recycled materials and native plantings conserves resources.

Utah DNR Office Project Details

Project Description: State government office building
Owner: Utah Department of Natural Resources
Architect: Gillies Stransky Brems Smith Architects, David Brems, Design Principal
Mechanical Systems: Colvin Engineering Associates
Electric Lighting Systems: Western States Engineering
General Contractor: Jacobsen Construction Company
Location: Salt Lake City, Utah
Size: 3 story, 105,000 square feet (9755 m²)
Construction Cost: $10 million
Date completed: May, 1996
Heating Degree Days: 5458
Cooling Degree Days: 1104

ENERGY PERFORMANCE
The chart below provides a comparison of projected building energy loads for the Utah Department of Natural Resources office building and a modeled reference case designed to meet Utah energy codes. The chart leaves out water heating and office equipment because these energy loads are not affected by daylighting and energy efficiency measures.

	Reference	UDNR Building	Percent Reduction
Lighting	24,500 Btu/ft²/yr (278 million joules/m²/yr)	12,100 Btu/ft²/yr (137 million joules/m²/yr)	51 percent
Cooling	7,600 Btu/ft²/yr (86 million joules/m²/yr)	800 Btu/ft²/yr (9 million joules/m²/yr)	89 percent
Space Heating	14,600 Btu/ft²/yr (166 million joules/m²/yr)	16,000 Btu/ft²/yr (182 million joules/m²/yr)	10 percent* (increase)
HVAC (fans, misc.)	8,200 Btu/ft²/yr (93 million joules/m²/yr)	2,300 Btu/ft²/yr (26 million joules/m²/yr)	72 percent
Total	54,900 Btu/ft²/yr (623 million joules/m²/yr)	31,200 Btu/ft²/yr (354 million joules/m²/yr)	43 percent

Auxiliary HVAC System: Variable air volume (VAV) system with economizer cycle, direct/indirect evaporative cooling and mechanical chillers for peak loads. Heating is provided by boilers and a perimeter finned-tube system. (*See text for explanation of heating load increase.)

DAYLIGHTING FEATURES
- High aspect ratio (east/west axis is more than twice as long as north/south axis)
- 8000 total square feet (743.2 m²) of glazing (high-performance low-e windows) on south and north
- Open floor plan and interior clerestory windows
- Exterior and interior light shelves on south side
- Dimming ballasts integrated with daylighting

ENERGY EFFICIENCY FEATURES
- R-25 roof [2 inches (5 cm) sprayed-on fire proofing, 3 inches (7.5 cm) polyisocyanurate, metal deck]
- R-28 walls [6-inch (15-cm) metal studs, fiberglass batts, 2 inches rigid insulation, stucco]
- T-8 fluorescent ceiling lamps and electronic ballasts
- Indirect lighting fixtures (30 foot candle ambient lighting levels)
- Occupancy sensors and daylight sensors for "on demand" lighting
- Economizer cycle direct/indirect evaporative cooling
- High-efficiency motors and variable speed drives
- Advanced computer-controlled energy management system

ENERGY COSTS
The predicted cost of energy for the reference case is $100,000 per year. The Utah DNR should only have to spend about $50,000 per year on energy bills for its new building, yielding an annual savings of $50,000. Note that the predicted dollar savings is about 50 percent, while the energy savings (measured in Btus) should be about 43 percent. This difference is due to the designers' focus on the relatively higher-cost lighting and cooling loads and less attention to the lower-cost (per Btu) heating loads.

ENVIRONMENTAL/HEALTH FEATURES
- Continuous ventilation system to control air quality and humidity
- Daylighting (generous view-window area)
- Water-conserving fixtures
- Landscaping with drought-tolerant native plants and drip irrigation
- Reclaimed wood, outdoor furniture made from recycled aluminum and plastic

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